Search for Sterile Neutrinos with a Radioactive Source at Daya Bay

Several recent experiments indicate that the standard three-flavor picture of neutrino oscillations may be incomplete, as recounted in [1]. It has been recently suggested that one or more sterile neutrinos, which weakly couple to the active neutrinos, might exist. In particular, the "reactor anomaly" [2], based on the re-evaluation of the nuclear reactor $\overline{\nu}_e$ flux [3], leads to the conclusion that the $\overline{\nu}_e$ produced in the reactor core oscillate into some sterile neutrino species at distances of less than $\sim$10 m from the reactor core. This would reduce the active $\overline{\nu}_e$ flux observed by experiments at distances greater than 10 m from the reactor and account for the 5.7% deficit observed between prediction and measurement.

Current data suggests a sterile neutrino mass on the order of 1 eV^2. In order to unequivocally test the sterile neutrino explanation of the reactor anomaly, it is necessary to build an experiment capable of detecting reactor $\overline{\nu}_e$ at baselines corresponding to the sterile neutrino oscillation length, of order 3 m.

Sterile neutrino searches can be carried out at these baselines by detecting $\overline{\nu}_e$ emanating from a compact β-decay source. Found in abundance in spent nuclear fuel (many PBq per spent fuel rod), ^{144}Ce has a long half-life (285 d) and decays to ^{144}Pr, whose decay creates a $\overline{\nu}_e$ above the threshold necessary for inverse beta decay. Such a decay structure allows time for fuel processing and transport while also producing the energetic beta decays necessary for the coincident inverse beta signature. The development of such a source and appropriate shielding is currently the subject of R&D efforts.

The far site detector complex of the Daya Bay reactor experiment is an excellent candidate for a $\overline{\nu}_e$ source experiment [4]. A ^{144}Ce source can be deployed in the far site water pool as close as 1 m to the active region provided by four submerged functionally identical liquid scintillator detectors. With position resolution on the order of 20 cm, $\overline{\nu}_e$ interaction rates can be mapped in the various active detector regions to search for fluctuations consistent with an L/E oscillation.

The systematics of such a measurement should be greatly aided by the sub-percent level characterization of detector response done during θ_{13} running at Daya Bay [5]. Continued running of the near sites during a sterile neutrino search would also provide sub-percent precision on the reactor $\overline{\nu}_e$ flux, the primary background source. The geometry of the far site additionally allows for re-deployment of sources in multiple locations, which would provide a valuable check on any possible oscillation signature. In contrast to other proposed $\overline{\nu}_e$ source experiments [6], deployments at Daya Bay will not involve the disturbing of the antineutrino detectors.

Figure 1 shows a diagram of a proposed setup. With an 18 PBq (500 kCi) source, the sensitivity of this arrangement for 1 year of data-taking is also shown to 95% CL. A $\overline{\nu}_e$ source experiment at Daya Bay provides an independent experimental method for testing the reactor antineutrino anomaly to high confidence level.

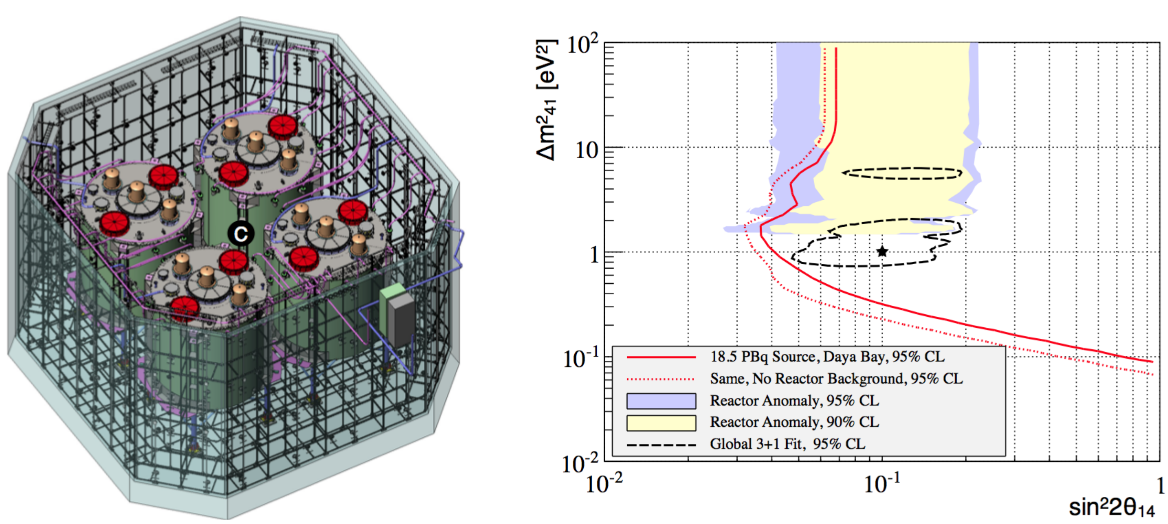

Figure 1: Right: Experiment layout of a proposed $\overline{\nu}_e$ source experiment at the Daya Bay far site. "C" denotes one possible source deployment location. Left: sterile neutrino oscillation sensitivity contours of the experimental setup using an 18 PBq source with 1 year of data-taking. Contours are 95% CL. From [4].

References

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